Water Event Early Warning System Executive Summary:

The KiTE solution can maximize Early Warning System (EWS) alerting for flooding, including in telemetry-poor regions and areas with underdeveloped mapping. The KiTE water intelligence platform contains hydrology models augmented by Machine Learning and Artificial Intelligence, in addition, the platform workflow capability provides the monitoring and collection capabilities, for before (preparation), during (response) and after (learning) an incident. Analytic processes and tools for social science help drive community engagement and include communication technologies for broad organizational collaboration and institutionalizing procedures.

Thus, the KiTE solution can collect and optimize knowledge of a region's hydrology, provide context to static flood maps by overlaying multiple different sources and provide forecasting based on a driving event, such as heavy rain and storms. The system is robustly proven in regions with minimal communications and has also been proven in different areas around the globe. It is a leading solution for Integrated Water Resource Management (IWRM) as recognized by the Global Water Partnership.

The solution is capable of integrating with a people-centered, all-society approach. KiTE incorporates information architectures that enable multiple inputs and coordination paths, with data views customized to different organizations and populations. Early warnings can thus be generated from an optimized combination of technologies, analysis and community participation across the society spectrum. This concept of an EWS is a consensus view global organizations and principal stakeholders in disaster management worldwide.

Scope of the Challenge and How KiTE can help:

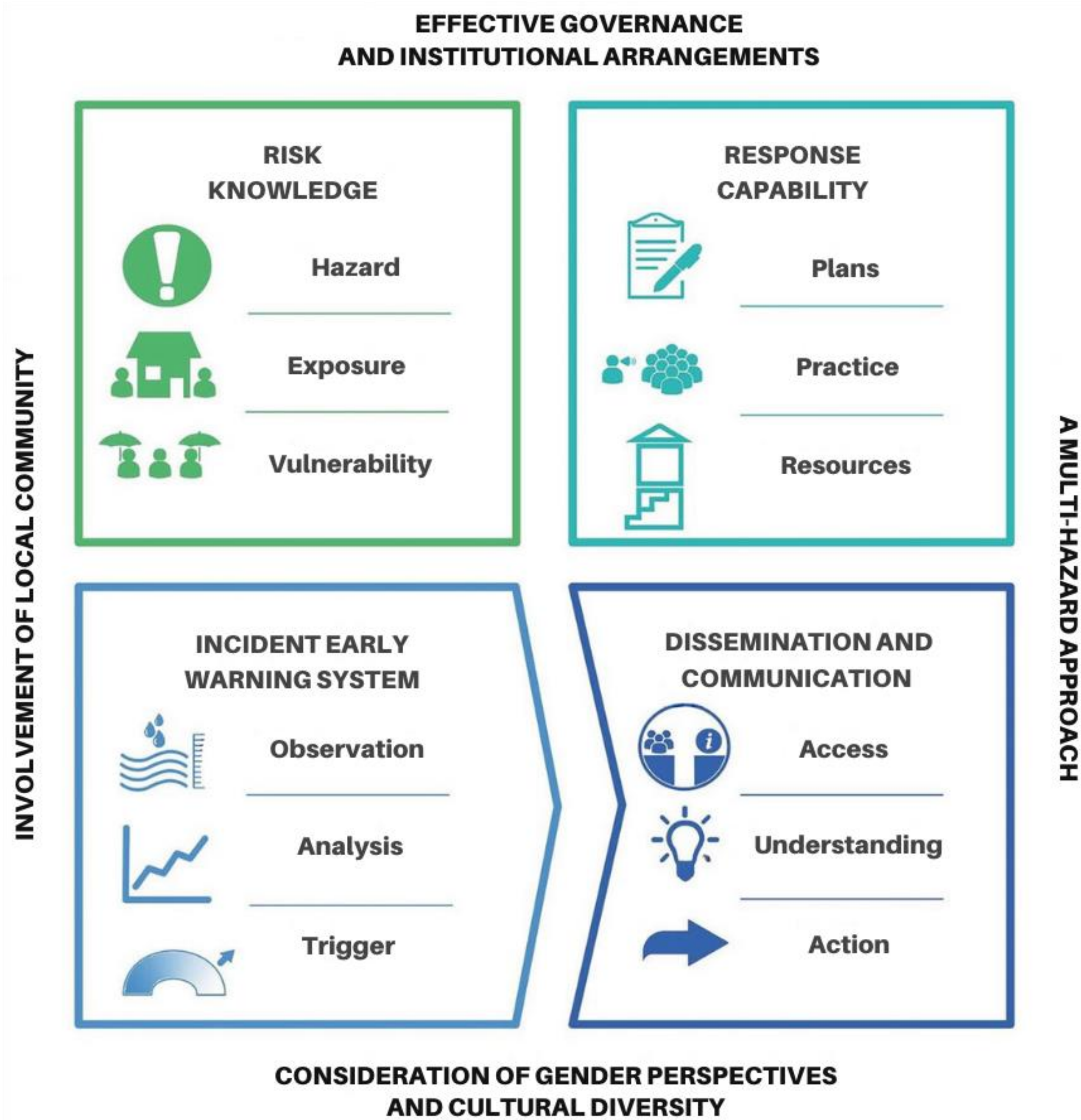
An overview of disaster early warning systems is extracted as follows from Early Warning Systems and Their Role in Disaster Risk Reduction, Robert Šakić Trogrlić et. al[1]

"Management of disaster risks requires that the nature and distribution of risk are understood, including the hazards, and the exposure, vulnerability and capacity of communities at risk. A variety of policy options can be used to reduce and manage risks, and we emphasize the contribution of early warnings, presenting an eight-component framework of people-centered early warning systems which highlights the importance of an integrated and all-society approach. We identify the need for decisions to be evidence-based, for performance monitoring and for dealing with errors and false information."

Trogrlić et. al further cite the World Meteorological Organization and United Nations Office for Disaster Risk Reduction have published a widely used and internationally recognized checklist for multi-hazard and people-centered early warning systems, outlining four main elements and four overarching

[1] Early Warning Systems and Their Role in Disaster Risk Reduction - Robert Šakić Trogrlić, Marc van den Homberg, Mirianna Budimir, Colin McQuistan, Alison Sneddon & Brian Golding https://link.springer.com/chapter/10.1007/978-3-030-98989-7_2#chapter-info

components of any early warning system (UNISDR 2006, WMO 2018b - Adopted from Brown et al. 2019).[2]



[2] Brown S., M. Budimir, A. Sneddon, D. Lau, P. Shakya and S. Upadhyay, 2019. Gender Transformative Early Warning Systems: Experiences from Nepal and Peru. Rugby, Warwickshire, United Kingdom: Practical Action. Available at: https://floodresilience.net/resources/item/gender-transformative-early-warning-systems-experiences-from-nepal-and-peru/

Trogrlić et. al have also compiled common gaps in EWS based on the literature (Basher, Grasso, UNDP, WMO, Zommers and Singh)[3] for these combined elements and components. The aspects of KiTE that address these gaps is listed in the summary below; the full list is included in the APPENDIX.

Components of early warning system / Gaps Mitigation Summary

Summarizing the EWS components, they are broadly categorized into data fusion (risk knowledge), knowledge creation (monitoring and warning), knowledge delivery (communication and dissemination and response capability), coordination (effective governance and institutional arrangements, multi-hazard approach) and community engagement (local community, gender perspectives and cultural diversity).

The KiTE system incorporates these categories synergistically. The data fusion leverages coordination and well as communication to enable first data fusion, then knowledge creation and finally knowledge delivery. Community engagement ensures a balanced approach for serving the people in the region. Several capabilities support coordination and engagement and include embedded and auditable operating procedures, data views by agency, layered cyber security, multiple means of system interaction and social science toolsets among others. This provides a path to preparation, familiarization, rehearsal, acceptance and finally proficiency in integration with the overall response process.

The design of the KiTE system addresses the complex and multi-faceted early warning challenge by unifying advanced technologies. The forecasting can be specific to a region, is multi-hazard for water events and contamination and is also climate change indexed. The solution is proven for communication and engagement in environments ranging from tropics to arctic and maritime to terrestrial. It is thus a capability that can maximize outcomes with the resources available.

Technology Discussion:

A principal challenge of an EWS is how to transform a normal state into a warning state that drives actions, response, and policies. In areas where telemetry and sensors are sparse the transformation is more difficult due to time lags. It takes time to report a disturbance, whether by sensors, organizations, or the community, then assess the report, and decide on a course of action. This time lag from disturbance to recognition by a controller/manager or operator is known as dead time. From a process control perspective, dead time is a major challenge[4].

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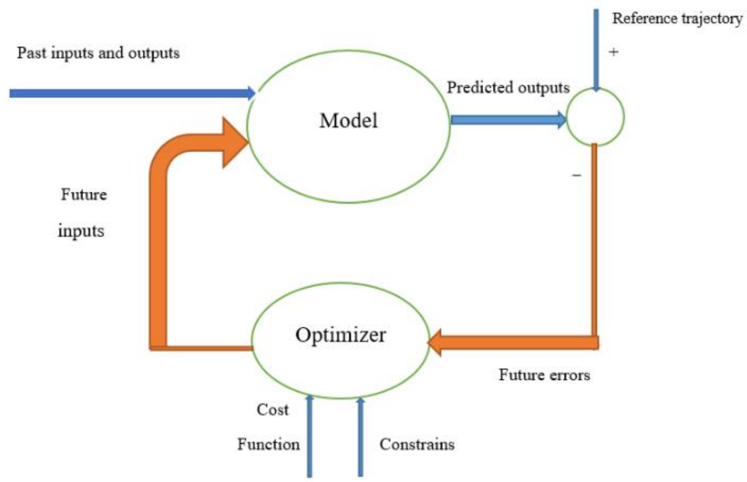
[3] Basher 2006, Grasso 2014, UNDP 2018, WMO 2015b, Zommers and Singh 2014
[4] https://controlguru.com/dead-time-is-the-how-much-delay-variable/ 'Dead Time is the Killer of Control'

The EWS is component of a broad organizational process composed of sensors and reports (inputs), as well as the response actions of managers and community (outputs). This ongoing relationship of inputs, time lags and outputs share several aspects with a process control situation. KiTE can mitigate the deadtime impact and accelerate the decision making and response cycle to improve response and optimized use of resources.



General diagram of model predictive control.

Figure 1

The KiTE water intelligence platform creates a model (Hydrology Digital Twin - HDT) of the water environment using scientific first principles, fusion of disparate data sources and augmented with Artificial Intelligence (AI) and Machine Learning (ML). The unique combination and display of the information further endows the platform with a forecasting capability that creates actionable information from the available inputs. This is somewhat similar in principle to model predictive control (MPC)[5]. One of the benefits of MPC is its ability to mitigate the impact of deadtime[6]. Figure 1 shows a typical MPC cycle with the components that correspond to an EWS. Namely A) a model based on past inputs and data (HDT) B) predicted outputs (forecasts) C) correlation with reference data (field reports, sensors) and D) optimization, which in the case of an EWS is response actions and policies.

The EWS is much broader and more multifaceted by an order of magnitude than the simple diagram in figure 1, but the key common aspect is forecasting / prediction that is leveraged for action on an ongoing basis. This prediction gives organizations and managers an edge in dealing with incidents.

The MPC principles are generally reflected in the KiTE process as well as leveraging of a rich fused and multi-sourced data repository that gives managers a full tool set for broad based assessments as well as predictions. This process is shown below as figure 2.

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[5] Jafari, Sadiqa & Shahbazi, Zeinab & Byun, Yungcheol. (2021). Improving the Performance of Single-Intersection Urban Traffic Networks Based on a Model Predictive Controller. Sustainability. 13. 5630. 10.3390/su13105630.

[6] Santos et al, Journal of Process Control Volume 22, Issue 1, January 2012, Pages 236-246

Figure 2

Step 1) Quickly assess risk – This is a starting point for overall situational awareness of the risks in an area based on historical data incorporated into the water intelligence platform UI.

Step 2) Translation of historical data into the body of the HDT model for monitoring and analysis.

Step 3) Intelligent forecasting from the model aided by AI and ML for multiple scenarios.

Step 4) Directed workflows based on analysis and predictive forecasting are delivered via multiple communication pathways.

Step 5) Field assessments are fed back into the process to complete the loop and update the platform.

About the Team

Kestrel Technology Group, LLC. of Sugar Land, Texas provides scalable knowledge management systems for field operations, command center awareness, command & control, and multi-source analysis across a broad array of applications. Kestrel's partnership with the USG and ASEAN partners beginning in 2006 and with the Philippines beginning in 2010, has developed and deployed the Field Information Support Tool (FIST), a leading-edge capability for intelligent workflows in the field.

Imaginet International, Inc. Is a comprehensive network infrastructure technology provider. Optical, RF and hard connections are integrated into cyber secure facilities with environmental controls and resilient green power. Imaginet and Kestrel have teamed to support US DoD security requirements since in 2014. Imaginet also supports vital Philippine Agency applications with hardened networks and managed security support.

True Elements, Inc. Is a global leader in environmental science and applications. Its flagship efforts for water address the pressing and crucial requirement for water understanding to inform policy analysis. Artificial Intelligence, data fusion and mathematical models create a capability for response and planning. True Elements is a US based company based in Naples, FL and is innovation focused with partners and customers.

APPENDIX – FULL EWS GAP LIST

Risk information:

a) A predominant focus on hazard with a lack of understanding of vulnerability and exposure
b) Lack of integration of risk information in decision-making
c) Data gaps – especially in developing countries
d) Difficult access to data for risk information – particularly open access/sharing across disciplines or organizations.
Comment: KiTE is highly impactful for aiding mitigation to vulnerability and exposure

Monitoring and warning:

a) Uncertainty in forecasting and climate change influencing forecasting capability
b) Varying skills of forecast information: accuracy, reliability, resolution
c) Lead time
d) Spatial and temporal resolution
e) Varying quality of historical data records limits prediction skill
f) Lack of validation/evaluation of forecast skill
g) Lack of monitoring infrastructure, technical and human capacity, especially in developing countries
h) Lack of sustainability of monitoring and forecasting systems
i) Inadequate monitoring
j) Prediction capabilities for rapid-onset hazards (e.g. flash floods and landslides) and lack of systems for some hazards (e.g. dust and sandstorms, flash floods)

Dissemination and communication:

a) Dominance of experts at the expense of user-focused communication
b) Top-down dissemination takes time, reducing lead time
c) Lack of feedback mechanisms between users and producers
d) Lack of access to warning information, especially for the most vulnerable groups
e) Inadequate communication systems to provide timely, accurate and meaningful warning information to those at risk
f) Underdeveloped dissemination infrastructure in developing countries
g) Lack of impact-based warning information
h) Inadequately standardized nomenclature, protocols and standards
i) Ineffective engagement of media and private sector
j) Fragmented monitoring responsibilities
k) Communication content/message not adapted for specific user needs/ capabilities

Response capability:

a) Weak public response to warnings
b) Lack of risk awareness and understanding – lack of outreach/education and practice
c) Lack of post-event reviews and poor incorporation of lessons learned

d) Unclear authorities and decision-making processes hindering the response
e) Lack of simulation exercises and evacuation drills
f) Lack of inducing long-term risk reduction behavior
g) Lack of adequate safe spaces, concerns over safe spaces, lack of safe routes
h) Barriers to acting even if would want to, e.g. caring responsibilities or insufficient lead time.
i) Concerns over leaving assets/possessions (guarding and staying put)
j) Behavioral reasons for not responding (e.g. risk perception based on previous experience of hazards and staying put)

Effective governance and Institutional arrangements:

a) Inadequate multi-agency and institutional collaboration and clarity of roles and responsibilities
b) Lack of funding (i.e. disaster finance still heavily focused on response)
c) Weak budgetary and political support in some countries
d) Inadequate coordination between local, national and regional levels
e) Gaps in legal, institutional and coordination frameworks, especially in developing countries
f) Political failures to act (e.g. timing, lack of resources, fear of litigation)
g) Weak integration of EWS in national plans
h) Inadequate recognition of links between disaster risk reduction, climate change adaptation and sustainable development
i) Insufficient coordination among actors responsible for EWS

Multi-hazard approach:

a) Most countries report warning systems for single hazards (i.e. lack of multi-hazard EWS)
b) Very few countries have all hazards covered. And rarely are they integrated (sharing data, risk analysis, interactions, one-communication channel/method, synthesized SOPs for response)

Involvement of local community:

a) Lack of engagement of those at risk is the design and operation of EWS
b) Practical challenges of community engagement (e.g. physical distance, funding, timeframes)
c) Lack of using participatory approaches
d) Lack of inclusion of local, traditional and indigenous knowledge

Gender perspectives and cultural diversity:

a) Gender incorporation in EWS rarely considered
b) Lack of consideration of cultural diversity and linguistic barriers
c) Marginalized people not included or considered in a meaningful way in assessment of risk and unable to participate meaningfully in DRR/DRM/EWS preparedness plans, etc.